Report No. 68-101-4
Contract NASW-417

# Bellcomm, Inc.

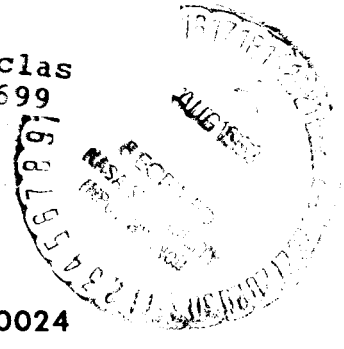
QUARTERLY PROGRESS REPORT

July August September

1968

I. M. Ross
President





Bellcomm, Inc.
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## ABSTRACT

The activities of Bellcomm, Inc., during the quarter ending September 30, 1968 are summarized. Reference is made to reports and memoranda issued during this period covering particular technical studies.

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# APOLLO/SATURN SYSTEMS ENGINEERING
# MISSION PLANNING

## Mission Assignments

Final distribution of the June 1968 issue of the Apollo Flight Mission Assignments document was made in early July. Preparations for the next issue are underway. This issue will include the C-Prime Mission and G-1 and G-2 mission appendices as well as a payload requirement range and uncertainty for each mission. Internal and center level reviews have been completed.

Test objective status was reviewed. A master chart for test objectives is being prepared. Test objective changes requiring the Apollo Program Director's approval have been brought to his attention and appropriate action taken. Primary mission objectives and detailed test objectives are being reviewed for validity and proper mission assignment.

Technical activities related to Apollo 7 included reviews of the detailed test objectives, the preliminary and final launch and flight rules, and the Mission Operations Report. Changes to the detailed test objectives were recommended at the Apollo Status Review meeting. Other Apollo 7 activities included participation in the resolution of weight tolerance and uncertainty allowance figures. An Apollo Mission E presentation was made to the Apollo Program Office.

## Vehicle Performance

Monthly preparation and delivery of Weight and Performance Reports continued.

A change to the launch vehicle/spacecraft payload interface from 100,000 lbs with a Flight Geometry Reserve (FGR) of 260 fps to 101,500 lbs with an FGR of 125 fps was negotiated with MSFC and subsequently approved by the Apollo Program Director. Associated changes to the Apollo Program Specification have been initiated.

Work was done toward a revised set of control weights and/or velocity budgets for the spacecraft. A revised MSC method for calculating LM propellant requirements was studied in depth and discussed with MSC. Material describing the revised approach was prepared and presented to the Apollo Program Office.

A performance scan for lunar missions from July 1969 through June 1970 was made. The results of that scan show that, with current CSM 107 and LM-5 weight and performance data, the highest injected weight during that period (99,100 lbs) occurs in February 1970. SPS fuel requirements for that month are 1,700 lbs below tank capacity.

## Mission Analysis

Requirements for lunar surface television coverage have been studied. The ability to provide lunar surface television coverage using the LM high gain S-band antenna will depend upon visibility by the 210 foot antenna at Goldstone and/or other stations of equivalent capability. An evaluation of Goldstone coverage for missions in the second half of 1969 has been made. In addition, data has been prepared to show the potential value of an existing Australian station to supplement the Goldstone coverage. The findings will be reviewed with concerned organizations at MSC.

A study was completed on the effects of glare on astronaut visibility during LM landing for approach paths into the sun. (1) It was concluded that if eyes are shielded from dazzle, acceptable visibility will be maintained for sun angles from 125° to 160° with window contamination three times as great as present experimental data predict.

The degradation of the ability to sight stars or to sight the LM tracking light due to RCS contamination of the spacecraft optics has been investigated. (2) It was concluded that RCS contamination is unlikely to cause significant degradation in the use of the CM Sextant, but that observations through the Scanning Telescope, LM Alignment Optical Telescope, and spacecraft windows may be seriously hampered even by very small amounts of contamination when the sun strikes the optics at angles of 60° or less.

## Trajectory Analysis

New lunar gravity models have been derived by Bellcomm from Lunar Orbiter tracking data and are being evaluated at MSC for possible incorporation into the real-time computer programming for Apollo missions.

The use of resonant orbits to determine lunar gravity models was studied and was determined to be unpromising. (3) Other studies of lunar orbit navigation and of the use of MSFN tracking data were continued. (4)

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(1) Reduction in Lunar Surface Visibility Due to Glare During a Landing into the Sun, TM-68-2013-5, R. Troester, September 30, 1968.

(2) Star Sighting Problems Due to Light Scatter from RCS Plume Residue on Apollo Spacecraft Optics, Memorandum for File, R. Troester, September 30, 1968.

(3) An Analysis of Orbital Resonance for the Determination of Lunar Gravitational Harmonic Coefficients, Memorandum for File, A. J. Ferrari, August 6, 1968.

(4) MSFN Navigation Support in Earth Parking Orbit, Memorandum for File, R. M. Scott, September 23, 1968.

A method has been developed for representing in a spherical harmonic form the gravitational potential of an array of small masses (not necessarily point masses) imbedded in a large body.

A study was made of a proposed two-burn lunar orbit insertion maneuver in which the initial burn produces an elliptical parking orbit. (5) From this study it was concluded that there is no strong technical argument either for or against the two-burn deboost as compared with the single-burn deboost.

A second study analyzed the use of an optimum two-burn deboost into lunar parking orbit which includes an intermediate coast arc in a circular parking orbit. This two-burn deboost provides for possible performance gains and permits two plane changes to be made. A trajectory scan was made for 1969. It was concluded that for first Apollo mission lunar landing sites the added complexity in targeting would not be worthwhile.

Full capability for generating optimum hybrid lunar mission trajectories has been developed. Hybrid trajectories already generated verify the feasibility of using only daylight launch opportunities for the entire year of 1969. The constraint that the LM descent propulsion system provide a safe earth return from the lunar vicinity in the event of SPS failure is satisfied. In addition, an investigation of hybrid mission performance to science sites outside of the Apollo zone is in progress.

Guidance Analysis

Studies of LM descent guidance were continued. A second presentation was made at MSC on pitch or look angle excursions as a function of landing radar updating over rough terrain.

A study was completed on the effects of center of gravity motion and initial thrust misalignment, verifying the expected errors during midcourse corrections. (6)

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(5) A Discussion of the Proposed Two Burn Lunar Orbit Insertion Maneuver, Memorandum for File, D. A. Corey, August 5, 1968.

(6) Initial Thrust Mistrim and c. g. Motion Effects on Translunar and Transearth Midcourse Correction Maneuvers, Memorandum for File, F. La Piana, August 22, 1968.

A memorandum was issued on a simple method of estimating the quantiles of the magnitude of a three dimensional vector. This technique is useful in estimating midcourse $\Delta V$ requirements. (7)

Flight Software Analysis

Bellcomm participation continued in the Apollo Guidance Software Task Force. Following the fourteenth meeting of the Task Force a final report was prepared and submitted to the Associate Administrator for Manned Space Flight for approval. (8)

Monitoring of spacecraft software was continued.

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(7) A Simple Method for Approximating Quantiles of the Random Variable $X_1^2 + X_2^2 + X_3^2$, Memorandum for File, H. J. Bixhorn, B. G. Niedfeldt, August 9, 1968.

(8) Final Report - Apollo Guidance Software Task Force, W. G. Heffron (Secretary, Apollo Guidance Software Task Force), September 23, 1968.

## Communications Systems

Mathematical analysis of the Unified S-Band (USB) system continued. A complete solution was obtained for the average power spectrum at the output of a limiter-phase detector similar to those used in the spacecraft and Manned Space Flight Network (MSFN) USB receivers. (9)

A summary memorandum on the analysis of the Apollo Up-Data System was prepared. (10) It was concluded that the present system design represents a reasonable balance between error rejection and the time used in transmitting data.

Radio frequency propagation between extravehicular astronauts and between extravehicular astronauts and the LM on the lunar surface was analyzed and the expected path loss versus link distance was determined. (11)

The performance of the communication link between the LM on the lunar surface and the earth without the use of the LM erectable antenna was reexamined. (12) Using the LM steerable antenna, all phase modulation (PM) modes were shown to have positive margins even with worst case tolerances. The frequency modulation (FM) modes were shown to range from marginal (for TV transmission) to virtually unusable (for EVA biomed back pack data).

## Launch Systems

Mission planning factors which are sensitive to hypergolic systems lifetime were developed for Apollo 7, Apollo 8, and AS-504 missions. An oral presentation was made to the Apollo Program Office. The current 30-day CSM hypergol systems lifetime limits the 8-day C-Prime mission to a single 3-day launch opportunity. Analysis of on-pad and mission timelines revealed that waivers extending the CSM hypergol lifetime to 34 and 62 days respectively would be required to fully cover C-Prime (Alternate) mission daylight launch

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( 9) A Statistical Analysis of a Bandpass Nonlinearity Phase Detector Cascade, TM-68-2034-14, W. D. Wynn, August 9, 1968.

(10) Summary of a Detailed Study of the Apollo Up-Data System, TM-68-2034-16, R. L. Selden, September 29, 1968.

(11) Propagation Characteristics of the Apollo Dual-EVA Communication Links, TM-68-2034-13, K. H. Schmid, August 12, 1968.

(12) Power Margins for the LM-MSFN (85') Communications Link at Lunar Range, Memorandum for File, N. W. Schroeder, September 23, 1968.

opportunities for (1) December 1968, and (2) December 1968, and January 1969.[13]

An analysis was made of the operations of Safing and Arming (S&A) device connect/disconnect and final Launch Vehicle/Range Command checks during launch countdown. A system description was prepared and an assessment of hazard versus safeguards was developed together with recommendations.[14]

Continuing the follow-up of the LM Supercritical Helium (SHe) system, an analysis was made of data obtained through a review held at MSC. Based on present MSC data, the system was shown to have a marginal lifetime for a lunar mission.[15]

Space Vehicle Systems

A simplified description of the LM thermal protection system was presented to the Apollo Program Office. Particular emphasis was given to recent changes aimed at weight reduction. It was noted that planned LM-3 flight data may not be adequate to verify ground test results used as the basis for the LM thermal control system design.

A study was conducted on the possibility of circuit breakers acting as ignition sources in cases of failure.[16] The design and test history of the breakers in Apollo spacecraft and the results of special tests in an oxygen environment conducted by MSC were reviewed. The results of this study support a conclusion that the circuit breakers used in Apollo are not likely ignition sources. A presentation of the results was made to the Apollo Program Office.

The need for fire resistant spacecraft materials in oxygen enriched atmospheres led to a search for thermally stable polymers and for rational models to allow prediction of flame spread in the resultant physical configuration. The search for materials has focused attention on polymers which contain

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(13) The Influence of CSM-103 Hypergol Subsystem Lifetimes on C Prime Mission Launch Opportunities, Memorandum for File, C. H. Eley, III, September 26, 1968.

(14) Range Safety System Operations During Saturn V Launch Countdowns, Memorandum for File, G. J. McPherson, Jr., August 14, 1968.

(15) LM Supercritical Helium (SHe) System - Status of Lunar Mission Requirements/Capabilities and Proposed Uprating, Memorandum for File, D. M. Duty, August 28, 1968.

(16) Apollo Circuit Breakers as Ignition Sources, Memorandum for File, W. H. Hodge, September 11, 1968.

aromatic substituents (a special case of electron delocalization) in the carbon backbone. A memorandum describing these materials was prepared.[17]

A review was made of flame propagation data for many solids. It was found that a simple power law relationship cannot accurately model the dependence of propagation rate on oxygen concentration. It is suggested that pyrolysis data and proper analysis of related processes may provide the physical basis for a model for predicting flame spread.[18]

Work was continued on evaluation of factors of flammability, physiology, hardware, and crew procedures affecting the choice of prelaunch cabin atmosphere for the LM. It was noted that the LM atmosphere at the time of crew entry in flight must have a high oxygen content to satisfy physiological requirements; however, prior to crew entry, a low oxygen content atmosphere is preferred to minimize the risk of fire. Provisions for exchanging the LM cabin atmosphere in flight were examined in terms of the impact on hardware and on crew timelines. The results of this study were presented to the Apollo Program Director with the recommendation that a low oxygen content atmosphere be used at launch and a means of venting the cabin be provided. If the impact of this approach on hardware or consumables were not acceptable, it was recommended that a 60% oxygen environment be used and that flammability tests be carried out to assess the hazard.[19]

A simplified longitudinal structural mathematical model for the AS-503 (CSM-103/LM-3) configuration was obtained from MSFC. Revisions were made to obtain better agreement with the results of the more complex structural models, and the simplified model was used to study the effect of weight changes on structural frequencies and mode shapes. It was found that payload weight changes had little effect on the frequencies of the longitudinal modes of the overall vehicle but did affect the amplitude to a larger extent than expected. Significant changes in the payload response in the higher vehicle modes were also noted.[20]

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(17) Electron Delocalization and Aromaticity: Their Effect on the Thermal Stability of Polymeric Materials, Memorandum for File, M. V. Drickman, September 20, 1968.

(18) Preliminary Findings--Flame Propagation Dependence on Atmospheric Oxygen, Memorandum for File, S. S. Fineblum, July 23, 1968.

(19) LM Launch Atmosphere Alternatives, Memorandum for File, R. D. Raymond, July 10, 1968.

(20) Influence of Weight Changes on AS-503 Structural Longitudinal Mode Shapes and Frequencies, Memorandum for File, H. E. Stephens, September 10, 1968.

A mathematical model of the space vehicle structure and the first stage propulsion system was developed in order to examine the stability of the space vehicle with respect to longitudinal (POGO) oscillations. A distributed model of the engine suction lines is incorporated rather than the usual lumped element approximation. Results to date indicate that the pre-valve accumulator modification selected by NASA to ameliorate POGO oscillations should provide adequate stability for the first vehicle mode. Further studies are concentrating on the oxidizer suction line second mode effects and oxidizer tank bulging mode effects. The results have been discussed with MSFC.

The tolerance and performance limits for a flight crew exposed to longitudinal and lateral vibrations were analyzed. Existing data indicate that vibration acceleration levels in any axis should not exceed about 0.4 g zero-to-peak between 2 and 20 Hz for reliable crew performance although tolerance levels are much higher. These data were reviewed with crew and medical representatives at MSC and with vibration specialists at Wright-Patterson Air Force Base. It was recommended that Apollo flight crew members be familiarized with the expected vibration environment through simulation training.

A set of vibration transfer functions for the crew couches in the CM was derived to permit extrapolation of POGO oscillation levels to the crew positions.

Mission Assurance

Efforts related to the activities of the Apollo Crew Safety Review Board included the identification of factors affecting safe abort in the presence of severe POGO oscillations and evaluation of the proposed extension of automatic Emergency Detection System (EDS) function through the first stage burn.

Surveillance of evolving space flight safety, rescue, and escape (S/R/E) concepts was continued. A summary relating Apollo Program activities and system features to S/R/E concepts was presented to the Apollo Program Office.(21)

Activities pertaining to the identification and elimination of failure points that could cause premature launch vehicle shutdown were concluded with the assessment of MSFC changes which would reduce by 55 the number of such single failure points.

Preliminary results of a space flight hazards identification study and a set of safety requirements applicable to orbital space stations were provided to the MSF Safety Office.

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(21) Safety-Rescue Escape APO Briefing, Memorandum for File, G. B. Troussoff, July 18, 1968.

## Natural Environment and Physical Standards for the Apollo Program (NEPSAP)

The review of the document "Natural Environment and Physical Standards for the Apollo Program" (NEPSAP) continued with a view toward (1) wider, more general space program application, and (2) updating of existing material to include the most recent scientific knowledge in each of the areas covered. A new draft entitled "Natural Environment and Physical Standards for Manned Flight Programs" to reflect the wider scope has been completed. Changes recommended by Center personnel have been incorporated.

## Radiation Studies

The problem of calculating the radiation dose in earth orbit produced by energetic electrons and their associated bremsstrahlung* was studied.(22) It was concluded that bremsstrahlung calculations are sufficiently accurate for present purposes but that additional Monte Carlo calculations of electron penetration of relatively thick shields (greater than 70% of the electron range) are needed for accurate electron dose calculations. A calculation of the electron dose in the Lunar Module for Apollo Mission E was made using recent Monte Carlo results. Electrons were found to provide the major contribution to skin dose in the Lunar Module, and the calculated daily dose was approximately a factor of two higher than earlier estimates. However, the dose was still within acceptable limits assuming the predicted decay of the artificially injected Starfish electrons to be correct.

The work of the MSC Radiation Constraints Panel has been reviewed. Some inputs have been made to the panel with respect to mission rules for radiation.(23) Specifically, it has been pointed out that mission rules can affect the total skin dose accumulated on a lunar landing mission to a significant extent, but not gastrointestinal tract doses.

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* Electromagnetic radiation due to particle retardation in an electric field.

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(22) Problems in Radiation Dose Calculations in Spacecraft, I: Electrons, TM-68-1011-3, J. S. Ingley, August 23, 1968.

(23) An Evaluation of the Concept of Crew Member Radiation Standards, Memorandum for File, R. H. Hilberg, R. K. White, September 30, 1968.

CSM Photography

Bellcomm participated as a member of the newly-established Lunar CSM Photography Working Group.(24)

A parametric study was performed on a variety of lens/film combinations for CSM cameras at various altitudes or ranges above the lunar surface.(25)

Work was initiated to adapt a computer program from the Lunar Orbiter Program to CSM lunar photographic decision making. It will be usable both for mission planning and for real-time decision making and will embody Lunar Orbiter experience and data which can benefit Apollo.

A two-color CSM photographic experiment has been proposed for the lunar orbital alternate profile on Mission C-Prime.(26) Successive photographs of each target on the lunar surface would be taken through a blue and a red filter using the hand-held Hasselblad with the 80 mm lens. The Whittaker sandwich method of printing would be used for data display and a resolution of 25-50 meters is anticipated. It is expected that the increase in resolution of 2 orders of magnitude over earth-based photographs will yield information on the color and perhaps related compositional homogeneity of the lunar surface and, in particular, of the Apollo sites.

Bellcomm as one of four co-investigators has been working with U. S. Geological Survey, the Principal Investigator, in preparing a proposal for a photography experiment from the CSM while in Lunar orbit. The major objective will be to increase the photographic coverage of scientifically interesting sites, both for their intrinsic value and for lunar exploration site selection purposes.

Apollo Surface Experiments

Bellcomm identified a need for additional thermal design verification testing on the Passive Seismic Experiment (PSE), and was requested to assist in the test design and test implementation. This activity has been pursued with discussions at MSC, at Bendix, and with the Principal Investigator. An analysis of the expansion of the LM ascent engine exhaust plume shows that the Apollo Lunar Surface Experiments Package (ALSEP) can be deployed 80 feet from the LM without experiencing a significant aerodynamic heating effect or receiving

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(24) Lunar CSM Photography Working Group Meeting on Lunar Photography for the C' and F Missions, Memorandum for File, D. D. Lloyd, September 24, 1968.

(25) Selection of CM Cameras for Apollo Lunar Photography, Memorandum for File, D. D. Lloyd, September 9, 1968.

(26) A Proposed 2 Color Photographic CSM Experiment, Memorandum for File, A. F. H. Goetz, September 20, 1968.

detrimental exhaust gas pressure.[27] Earlier studies had concluded that ALSEP must be deployed at least 500 feet from the LM to escape these problems.

Apollo Contingency Science

In response to the NASA decision not to carry ALSEP on the first lunar landing mission, several experiments were assessed as candidate contingency experiments.

An analysis of the advantages and disadvantages of the major candidates for a contingency program (PSE and Laser Ranging Retro-Reflector, $LR^3$) concluded that development of the contingency passive seismometer would have least perturbation on the nominal ALSEP Program.[28] However, the study concluded that a passive seismometer for the contingency program should be developed if and only if a one-year lifetime can be guaranteed. All other specifications (except sensitivity) should be subordinated to the lifetime requirement. That is, dynamic range, temperature control, duty cycle, bandwidth, and command capability can be sacrificed, if necessary, in order to develop a long-life instrument within the time available.

Due to the rigorous requirements on the corner reflector in order to have a successful experiment, and the lack of extensive technological experience in this area, it was concluded that the ALSEP $LR^3$ Program should not be diverted to build a reflector for the contingency program since it may be of marginal utility.

Lunar and Planetary Science

Bellcomm participation on the Space Science Board Panel on Planetary Astronomy has ended. The final report has been published by the National Academy of Sciences.

Preparation of text material continued for the forthcoming Lunar Orbiter Project Office publication, "The Moon As Viewed by Lunar Orbiter."

Bellcomm has been cooperating with the California Institute of Technology telescopic infrared study of Apollo sites. Good data has now been obtained on sites IIP6, IIP8, IIIP11, and Aristarchus. Observations of Plato have shown anomalies which coincide with previous 1966 experiments exactly, demonstrating the reproducibility of the method.

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(27) Safe Distance for the ALSEP Emplacement, Memorandum for File, G. K. Chang, August 22, 1968.

(28) ALSEP Derived Contingency Science, Memorandum for File, M. T. Yates, August 23, 1968.

A new theoretical model for the magnetic response of the moon to time variations in the interplanetary magnetic field has been proposed.(29) This model relates magnetic field measurements on the lunar surface to the properties of the lunar interior. If the electrical conductivity of the lunar core lies within the range of 0.01 to 10 mho/m as expected on the basis of theoretical and empirical considerations, the new model provides a quantitative method of interpreting the time response of a single ALSEP magnetometer, placed on the sunlit side of the moon, in terms of the core conductivity. This may also yield indirect information on the thermal properties of the lunar interior.

Lunar Mission Studies

Studies were conducted to assess relative merits and associated costs of candidate launch vehicles and upper stage systems for application as unmanned lunar payload delivery systems during the 1972-75 time period. The results indicate that Titan IIID/Centaur and Saturn IB/Centaur are the two potential candidates for unmanned lunar logistic systems. The Titan IIID/Centaur can deliver approximately 3,300 lbs of useful payload to the lunar surface as compared to approximately 5,100 lbs for the Saturn IB/Centaur. Economic considerations alone make a strong case for the application of Titan IIID/Centaur. However, other factors such as possible availability and higher payload capability are attractive features in favor of Saturn IB/Centaur. The option of developing a common landing stage/spacecraft for the two logistic systems would provide a flexibility of intermediate size payloads with the final vehicle choice dependent upon cost, availability, and mission objectives.(30)

A detailed study on the use of the Apollo sextant and LM Optical Rendezvous System as aids for pinpoint landing an unmanned Lunar Payload Module (LPM) was performed.(31) The study concluded that for exploration sites equivalent to Apollo sites, a $1\sigma$ accuracy of about 200 meters could be obtained, subject to feasibility of the operational technique. Studies in the areas of sextant tracking simulation and guidance software were suggested to validate these results.

The compatibility of a CSM aided LPM landing in conjunction with a manned CSM 14-day lunar orbital mission was investigated.(32) It was

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(29) Response of the Moon to the Time-Varying Interplanetary Magnetic Field, Paper submitted for publication to the "Journal of Geophysical Research", J. L. Blank, W. R. Sill.

(30) Unmanned Lunar Logistic Systems, Memorandum for File, R. Sehgal, September 9, 1968.

(31) Pinpoint Landing for a Lunar Payload Module, TM-68-2015-4, H. W. Radin, September 16, 1968.

(32) LPM Landing and 14 Day CSM Orbital Missions, Memorandum for File, I. Silberstein, August 12, 1968.

determined that a capability of landing the LPM at any given point on the moon and retaining a continuous abort capability exists, but is achieved at the cost of reduced areal coverage for the CSM portion of the mission. A 14-day polar orbit mission while landing the LPM at any point on the lunar surface is possible if the time limit on the LPM descent activation is removed.

Lunar Exploration Planning

Studies were performed to investigate improvements in Apollo capability for lunar exploration and a presentation was given to NASA on August 19. The topics included tradeoffs between lunar surface payload and returned payload, descent engine Isp and ascent engine Isp, CSM capability, and LM separation weight. Potential improvements obtainable from hybrid and non-free return trajectories were also discussed.

Assistance was provided to the Apollo Lunar Exploration Director in preparation of the Planning Source Documentation and the final version of the Program Memorandum.

Site Selection

Bellcomm chaired a meeting of the Site Selection Subgroup of the Group for Lunar Exploration Planning (GLEP) at MSC.[33] Six science-biased sites were recommended as candidates for the second Apollo mission, twelve sites were selected for analysis in FY 1969, and areas on the moon's earthside were identified which require further photography.

Bellcomm participated in the initial meeting of the C-Prime Mission Site Selection Subgroup. A tentative selection of photographic targets was made. Areas were identified for which data must be supplied to support mission planning.

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(33) Minutes of the (GLEP) Site Selection Subgroup Meeting of June 19, 1968, Memorandum for File, F. El-Baz, July 3, 1968.

## Weight Reporting

AAP Weight and Performance Reports for the months of July, August, and September were prepared, summarized for the AAP Director, and issued to Headquarters, KSC, MSC, and MSFC.

## Mission Assignments

A draft revision of the AAP Flight Missions Directive has been prepared to replace the issue of January 1967. Recent configuration, cost, and schedule reviews have resulted in a program baseline which defines three primary and one backup mission and which identifies backup launch vehicles and spacecraft elements.

## Mission Analysis

Investigation of the unmanned rendezvous of the Lunar Module/Apollo Telescope Mount (LM/ATM) with the Orbital Workshop (OWS) continued. In particular, effort has been focused on the determination of possible guidance and navigation errors during the rendezvous phase of the mission. A complete digital simulation of the rendezvous including the guidance system is being developed.

The computation of ground site visibility has been improved by the inclusion of the effects of dynamic changes in atmospheric density into two earth orbital trajectory simulation programs developed previously.(34) The performance of both programs shows a significant increase in accuracy compared to their earlier capability.

Further work was done on the RCS propellant budget requirements for the AAP CM-SM flights.(35) Comparison of the AAP budgets with those prepared for Apollo earth orbital missions reveals close agreement for all corresponding mission phases except rendezvous for which AAP has larger propellant quantities allocated. It was found that detailed differences in rendezvous profiles between Apollo and AAP account for a portion of the difference in the budgets. Beyond that, however, rendezvous propellant budgeting is based on analysis tempered by engineering judgment as to how Gemini flight results and man-in-the-loop simulation data should be applied to future rendezvous situations.

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(34) Application of a Dynamic Density Model to the Simulation of Earth Orbit Trajectories, TM-68-1025-2, A. B. Baker, September 23, 1968.

(35) Determination of SM RCS Propellant Requirements for AAP and Apollo Rendezvous, Memorandum for File, K. E. Martersteck, July 26, 1968.

Present AAP rendezvous budgets appear to be reasonable when the importance of the rendezvous to mission success is considered.

Alternate Mission Studies

Alternate missions for achieving the objectives of the solar astronomy mission (ATM mission) were studied.(36-48) As used here, the alternate or decoupled missions represent a special case of ATM contingency missions in which the decision not to cluster the OWS, LM-ATM, and CM-SM is made prior

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(36) ATM Alternate Mission Study, (A compilation of the following 12 references), MLS/Bellcomm, September, 1968.

(37) ATM Alternate Mission Study, Memorandum for File, G. M. Anderson, September 6, 1968.

(38) Spacecraft Weight Summary for CM-SM/LM-ATM Backup Missions, Memorandum for File, W. W. Hough, August 13, 1968.

(39) ATM Alternate Mission Study-Performance Analysis, Memorandum for File, I. Hirsch, K. E. Martersteck, September 3, 1968.

(40) Solar Viewing Capability in High Inclination Circular and Elliptical Orbits, TM-68-1022-5, B. D. Elrod, September 5, 1968.

(41) Scientific Evaluation of Alternative ATM Missions at High Inclination, Memorandum for File, D. B. Wood, August 6, 1968.

(42) Pointing Stability of a CM-SM/LM-ATM, Memorandum for File, J. Kranton, August 14, 1968.

(43) Gravity-Gradient Momentum Dumping for a CM-SM/LM-ATM Mission, Memorandum for File, W. Levidow, September 6, 1968.

(44) CM-SM/LM-ATM Alternate Mission Study - Electrical Power Requirements, Memorandum for File, B. W. Moss, September 9, 1968.

(45) Structural Considerations in CM-SM/LM-ATM Backup Mission, Memorandum for File, W. W. Hough, August 13, 1968.

(46) Radiation Doses for the CM-SM/LM-ATM Alternate Mission Study, Memorandum for File, R. H. Hilberg, J. S. Ingley, August 14, 1968.

(47) ATM Alternative Mission Study: Impact of Computer Systems, Memorandum for File, R. T. Kleiner, B. H. Liebowitz, P. S. Schaenman, August 9, 1968.

(48) ATM Alternative Mission Study- Communications Coverage, Memorandum for File, J. P. Maloy, August 12, 1968.

to the launch of both the latter two spacecraft. The decoupled orbital configuration employs successively launched LM-ATM and CM-SM spacecraft docked along the axis of symmetry, and flown with this axis aligned with the solar vector. The alternate mission studies covered the following areas: Spacecraft Weight, Performance Analysis, Solar Viewing, Scientific Yield, Attitude Control, Electrical Power, Structures, Radiation Dose Levels (for men and film), Computer Systems Impact, and Tracking and Communication Coverage.

Missions with durations up to 56 days at inclinations of $28.5^{o}$, $50^{o}$ and $63.5^{o}$ were studied. Both circular and elliptical orbits were examined. Among the conclusions reached were the following:

1. The 56 day Cluster Mission is superior to the 28 day alternate missions in terms of expected scientific yield.

2. Alternate missions can essentially meet the ATM experiment requirements provided it is feasible to schedule the crew so as to provide continuous manning of the ATM experiments. A high inclination orbit, approximately $50^{o}$, and a solstice launch are preferred.

3. The best way to increase the effectiveness of the alternate missions is to extend duration beyond 28 days.

4. Major system modifications to the CM, SM, LM-ATM, or S-IB are not required.

## APOLLO APPLICATIONS SYSTEMS ENGINEERING PERFORMANCE AND DESIGN REQUIREMENTS

### Baseline Configuration

Major configuration problems were identified and Center participation was coordinated for an Apollo Applications Program Review held on July 23 and 24, a Weight Reduction Meeting on August 7, and a Weight and Performance Review on September 26. Minutes of these meetings and lists of action items were prepared, approved by the AAP Program Director, and distributed.

Following review and coordination with the Centers, the Apollo Applications document, "Baseline Configuration Definition AAP-1 through AAP-4," was revised, approved by the Program Director, and issued with an effective date of September 1, 1968.

A third meeting of the Multiple Docking Adapter (MDA) Task Force was arranged for August 22. This meeting was called to review the experiment assignments to the MDA with emphasis on earth resources and medical experiment integration in the MDA. Minutes of the meeting and action items were distributed.

### Electrical Power Systems Studies

The current status of roll-up solar array development under JPL monitored contracts was reviewed.(49) This technology gives promise for future programs of producing power at 30 watts/lb compared to about 2.5 watts/lb in present designs.(50)

Power requirements for AAP-3A were analyzed.(51) It was found that the 700 watts of power required by the CM can be supplied by the Airlock Module (AM) while retaining a positive margin for the OWS of approximately 600 watts.

Factors influencing the design of nickel-cadmium battery systems were reviewed.(52) Failure modes and the effects of operating temperature and

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(49) Lightweight (Roll-up) Solar Array Development, Memorandum for File, J.J. Sakolosky, August 5, 1968.

(50) Performance Improvement for AAP-2, Memorandum for File, B.W. Moss, August 5, 1968.

(51) Electrical Power Requirements for AAP-3A, Memorandum for File, B.W. Moss, July 19, 1968.

(52) Nickel-Cadmium Secondary Batteries, Memorandum for File, B.W. Moss, August 12, 1968.

depth of discharge on cycle life were described. It was found that insufficient data are available to specify operating conditions to guarantee a desired performance level.

A method of supplying oxygen to the space cabin atmosphere through the utilization of off-peak electrical power for the electrolysis of water was compared to the method of oxygen supply through cryogenic storage.(53) The comparison was made for both closed and open loop oxygen supply systems. The conclusion reached was that off-peak water electrolysis did not offer any significant weight reductions unless it was combined with a closed loop oxygen supply system utilizing the Sabatier reaction for $CO_2$ reduction.

Structures

Contending unmanned payload enclosures and suborbital jettison techniques for the AAP-2 and AAP-4 missions were examined.(54) Four-piece clam shell jettison of the Apollo Spacecraft Lunar Module Adapter (SLA) plus a segmented nose cone will give at least 300 pounds more payload-to-orbit than the proposed SA-203 type skin and stringer enclosure. However, the later enclosure offers a substantial cost saving if it is manufactured in-house by MSFC.

Environmental Control System

The requirement for a gaseous oxygen (GOX) accumulator to support Extra Vehicular Activity (EVA) and the Astronaut Maneuvering Unit experiment, M-509, was verified.(55) The design based on two LM Descent Stage GOX tanks meets the requirements.

Thermal Systems Studies

Present conventional techniques of spacecraft thermal analysis and the validity of these techniques were studied and reported to the AAP Director. These studies included a review of the analytical results in several selected unmanned programs as well as Gemini and Apollo.(56)

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(53) This was subsequently reported in A Look at Utilization of Off-Peak Electrical Power for Water Electrolysis, Memorandum for File, J.J. Sakolosky, October 8, 1968.

(54) Jettisonable Enclosure for Unmanned AAP Payloads, Memorandum for File, W. W. Hough, September 30, 1968.

(55) This was subsequently reported in Requirement for an Oxygen Accumulator on AAP-2, Memorandum for File, W. W. Hough, October 1, 1968.

(56) Correlation of Predicted, Ground Test, and Flight Thermal Behavior in Apollo, Memorandum for File, D. P. Woodard, September 5, 1968.

Thermal mathematical modeling and computing methods are being reviewed. Computer programs are being assembled and extended where necessary. Two computer programs have been obtained from the Goddard Space Flight Center and adapted for Bellcomm computer use. One of these programs computes the projected areas normal to the solar vector for certain arbitrarily-oriented bodies. The second program computes orbital incident flux from direct solar, earth albedo, and earth-emitted infrared sources. Modifications to increase the general utility of these programs were documented.(57) Introduction and check out of CINDA-3G, a general purpose thermal analyzer program, is in process and sample problems have been run.

Thermal control systems for the AAP CM-SM, Lunar Module Ascent Stage (LM-A), ATM, MDA, AM, and OWS were studied for the purpose of preparing descriptions of these systems. The descriptions for the LM-A and MDA were completed.(58, 59)

Attitude Control Studies

The simulation of the ATM Pointing Control System (PCS) has been augmented to permit a finer assessment of its ultimate pointing capability. Specifically, the following features have been added: (1) a stochastic model of crew motion disturbances, (2) sensor noise, (3) an optimum filter in the Experiment Pointing System to minimize rms pointing error, and (4) vibrational properties of the telescope structure.

A computer program has been developed to calculate the times that the sun, planets, and stars can be viewed from any circular or elliptical earth orbit. Viewing time profiles on long duration missions are obtained by accounting for the rotation of the orbit's line of nodes and line of apsides.

A study has been completed on a single rotation, two maneuver Control Moment Gyro (CMG) gravity-gradient dump procedure for both the AAP Cluster and the CM-SM/LM-ATM decoupled vehicle.(60) This procedure could be implemented as a manual backup procedure for the Cluster or as the primary procedure for the decoupled vehicle. Maneuvering is done during orbital darkness to allow full use of orbital daylight for solar experiments. Depending upon

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(57) Spacecraft Shadowing and Thermal Flux Computer Programs with Sample Problems, Memorandum for File, J. W. Powers, July 8, 1968.

(58) LM-A Thermal Control System, Memorandum for File, D. P. Woodard, September 27, 1968.

(59) Multiple Docking Adapter Thermal Control System, Memorandum for File, J. W. Powers, September 30, 1968.

(60) A Single Axis, Two Maneuver Gravity-Gradient Dump Procedure for AAP-ATM Missions, TM-68-1022-4, W. Levidow, September 20, 1968.

launch date, a 28 day decoupled mission in circular orbit requires up to 340 lbs of propellant if only reaction thrust dumping is used. When supplemented by gravity-gradient dumping, only 75 lbs are required. Similarly, gravity-gradient dumping reduces the dump propellant requirement for a 56 day Cluster mission from 286 lbs to 20 lbs.

A study was made of the attitude stability, relative to local vertical coordinates, of a spacecraft containing a gyrostat (e.g., a CMG with locked gimbals).(61) Gravity-gradient torques alone were considered. It was found that equilibrium attitudes which were unstable became asymptotically stable with the addition of the gyrostat oriented normal to the orbital plane.

The technical and cost factors leading to the selection of a new bipropellant attitude control system for the OWS were reviewed at the request of the Program Manager. The review confirmed that the design approach selected by MSFC is superior to the available alternatives considering cost and system weight criteria.

Spaceborne Computers

A brief study was conducted for the AAP Director to determine the need for a new spaceborne computer to support ATM functions.(62) It was concluded that the LM guidance computer (LGC) could probably handle the ATM requirements in addition to its expected AAP Guidance and Navigation functions, provided a new input/output (I/O) box was developed. However, the technical advantages, lower risks and greater simplicity of the new computer approach, plus the potential reduced cost, overshadowed the advantage of dealing with a familiar machine. It was therefore recommended that a new computer be procured for the ATM mission.

Communication Studies

A review of four intercenter Instrumentation and Communication Interface Control Documents was completed and comments and recommendations were forwarded to the AAP Instrumentation and Communications Panel.(63) The documentation covered the interfaces between the MDA and the AM, the LM-A/ATM and the MSFN, and the MDA/AM/OWS and the MSFN. The fourth document was the Saturn/AAP Frequency Plan.

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(61) Stability of Attitude Motion of an Orbiting Vehicle Containing a Gyrostat, TM-68-1022-8, E. Y. Yu, September 30, 1968.

(62) Selection of a Digital Computer to Support ATM Functions, Memorandum for File, P. S. Schaenman, September 4, 1968.

(63) Review of AAP I/C Panel Instrumentation and Communications Interface Control Documents, Memorandum for File, A. G. Weygand, July 19, 1968.

The status of electromagnetic interference (EMI) control within the Apollo Applications Program was reviewed.(64) The electromagnetic compatibility (EMC) control programs of both MSFC and MSC, which include EMI control specifications and EMC testing philosophy, are the same as their corresponding EMC control measures within the Apollo Program. The AAP Electrical and Instrumentation & Communications panels have the EMC responsibilities for AAP. Specific test plans to demonstrate EMC of the integrated AAP space vehicle cannot be developed until the master test flow plan for AAP has been formulated by the Test Definition and Planning Group.

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(64) Status of Electromagnetic Interference Control in the Apollo Applications Program, Memorandum for File, A. G. Weygand, September 5, 1968.

## APOLLO APPLICATIONS SYSTEMS ENGINEERING
## SCIENTIFIC STUDIES

### Experiment Evaluation

Comments and observations arising from the Critical Design Review (CDR) of the ATM Experiment S-054 X-ray Spectrographic Telescope were provided to the AAP Director for inclusion in the Headquarters' comments to MSFC. (65) The shutdown of ATM experiment canister electrical power for astronaut safety during EVA leads to a significant temperature drop due to the prolonged interruption of experiment heating. This requires further thermal analysis to establish the time of regaining thermal stability after each EVA and assessment of this impact upon the solar observation timeline.

The comments and recommendations generated following the CDR of the Naval Research Laboratory experiments S-082A, XUV Coronal Spectroheliograph, and S-082B, XUV Spectrograph, were submitted for inclusion in the Headquarters' evaluation of the review. (66) The scope of comment included structural and thermal analysis, vibration, maintainability, failure modes, and configuration. Recommendations were made to improve electromechanical features of the experiment designs.

### Natural Environment

Revision of the document, "Natural Environment and Physical Standards for the Apollo Program," (NEPSAP) continued in order to update the document and expand its application to all manned flight programs. Discussion of this activity appears on page nine under APOLLO/SATURN SYSTEMS ENGINEERING, SCIENTIFIC STUDIES.

### Experiment Time-Sharing

The time requirements for the ATM experiments as determined by the principal investigators were reviewed. (67) The possibility of time-sharing between experiments was examined and a reduction in total experiment operating time was shown to be feasible.

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(65) Critical Design Review of ATM Experiment S-054, X-ray Spectographic Telescope, Memorandum for File, S. H. Levine, T. C. Tweedie, Jr., July 15, 1968.

(66) Critical Design Review of the ATM S-082A XUV Coronal Spectroheliograph and the S-082B XUV Spectrograph Experiment, Memorandum for File, S. H. Levine, T. C. Tweedie, Jr., August 28, 1968.

(67) ATM Experiments - Time Requirements, Memorandum for File, A. N. de Gaston, August 1, 1968.

## Color Photography of Earth Resources

Analysis of the high-resolution color photographs from the unmanned AS-502 mission of April 4, 1968 continued. These photographs were examined for their scientific information content. (68) It was concluded that:

1. Automated stereo color photography is an excellent base for cartography and for geographic, topographic, and other surface studies that rely on the size and shape of terrain and man made objects.

2. Automated stereo color photography gives partial support to studies in agriculture and geology which require a base map in addition to color and brightness information of objects. Additional spectral information is needed from other analytical experiments to fully satisfy space sensing requirements in these disciplines.

3. The dynamic systems in oceanography and meterology cannot be studied very well by limited photography. Automated, unmanned TV cameras are of greater use in these disciplines. However, some interesting features of scientific interests, such as subsurface topography, coastal changes, wakes, frontal pattern, etc., can be identified. Also, cloud heights and inversion layers can be identified in stereo pictures by other means.

4. The usefulness of future stereo coverage can be largely increased if field authorities are consulted earlier in the planning.

5. Some technical problems, which may be optical or mechanical and pertain to the camera or the copying process used, are in need of attention. Successive pictures are often not identical in color shade, resolution, and brightness of objects in different portions of the frame (center vs. fringes). This technical flaw makes the interpretation of the photos more difficult. In addition to equipment upgrading, ground calibration experiments would probably help.

## Evaluation of Earth Sensors

A detailed study was made of the possible support to earth resources and meteorology that could be obtained by adding earth looking experiments to the AAP cluster. (69) The 14-experiment package previously proposed for the AAP-1A mission was assumed to represent the present capability for experimentation

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(68) Preliminary Evaluation of AS-502 Color Photography of Earth Resources, Memorandum for File, B. E. Sabels, July 19, 1968.

(69) AAP-1A - A Baseline Instrument Package for Earth Sensing, Memorandum for File, W. W. Elam, July 15, 1968.

on such a cluster. The possible support to twenty-four earth resources and fifteen meteorology sub-disciplines provided by these experiments was developed. This experiment package provides support to earth resources and meteorology in general. Certain sub-disciplines are not adequately supported by this experiment package. In some cases additional experiments would have to be added and in others improved instruments would be required to provide a uniform level of support for all sub-disciplines.

## ADVANCED MANNED MISSIONS SYSTEMS ENGINEERING PROGRAM REQUIREMENTS

### Earth Orbit

A draft of the Extension of Manned Space Flight Program Memoranda was prepared for OMSF. Alternative program plans for an Earth Orbital Space Station to follow the Apollo Applications Program, and the associated rationale and resource requirements were documented as part of NASA's planning prior to submission of the FY 1970 budget request. The source material supporting this memoranda was prepared and coordinated, and compiled into the required Program Support Documentation.

A space station program based on the exclusive use of Titan IIIM, Gemini and three relatively small specialized space stations was examined. (70) The program was required to fulfill the needs of the maximum science and applications payload developed during the Saturn V Workshop study (reported in the previous Quarterly Progress Report). It was concluded that such a program would not significantly differ from the Saturn V Workshop in either cost or achievement and could possibly provide more program flexibility.

A comparison was made of the space station development costs presented in contract studies in support of program analyses. (71) Three studies were selected to form the basis of this analysis: the Earth Orbiting Space Station study by Douglas Aircraft (now McDonnell Douglas Aircraft), the Manned Orbital Research Laboratory study also by Douglas, and the Basic Subsystems Module study by General Dynamics. The studies were examined to determine the means by which the contractors established the projected development costs and the categories of activity which were included in the cost figures. It was determined that the studies were in good agreement, and the projected cost for the development through flight readiness at KSC is approximately $600 million.

Several alternative programs were developed to determine the penalty associated with making the wrong assumption of the need for an artificial gravity environment in a space station. (72) The alternatives considered were to:

1. Start with no provision for artificial gravity and introduce such provisions as the need is demonstrated.

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(70) A Titan-IIIM Launched Space Station Program, Memorandum for File, E. D. Marion, J. A. Schelke, July 23, 1968.

(71) Workshop Cost Estimates Based on EOSS, MORL, and BSM Costs, Memorandum for File, A. E. Marks, July 25, 1968.

(72) To "G" or not to "G", Memorandum for File, E. D. Marion, September 24, 1968.

2. Start with a design that provides the capability to incorporate artificial gravity if the need arises.

3. Provide artificial gravity.

The logic developed indicates that a relatively small schedule and cost penalty is incurred by adopting the second alternative. This course costs only slightly more than the first alternative if the need for artificial gravity does not develop. If the need for artificial gravity did develop, it would provide the required capability slightly later with a slightly higher cost than the third alternative. Adopting either of the extreme strategies would incur a relatively large penalty if the wrong course were selected initially.

Advantages and disadvantages resulting from rotating space systems to provide aritificial gravity were reviewed. (73) Potential benefits lie primarily in the realm of improving habitability and maintaining physical fitness. Disadvantages include a tendency of free-falling objects to follow "non-vertical" trajectories, changes in body weight and body-posture during translation, differences between head and foot acceleration, and generation of Coriolis forces possibly affecting postural reflexes, locomotion, and manual tasks. On the basis of present-day knowledge, it appears that a gravity level of at least 0.3 g is suitable for habitability and that an angular velocity of not higher than 6 rpm is physiologically acceptable. Both ground-based and inflight research activities are required to define these limits and to identify other limits.

Guidelines were presented for assembling multi-discipline experiment payloads for Earth Orbital Space Stations in the 1970's. (74) It was suggested that payloads be selected to explore and extend manned system capabilities for long duration and reliability while accomplishing as much useful science as possible within funding and design constraints. Experiment programs in biomedicine, biotechnology, and manned operations should have first priority, at least in early missions. Astronomy deserves high priority as a program likely to best utilize man while making major scientific advances. Earth applications may take advantage of manned systems for early Research and Development operations. Other disciplines of advanced technology, bioscience, and physics have useful smaller payloads that are not mission-shaping. Three levels of experimental effort were identified for program planning. The experiments added at each level are: (1) basic biomedical and operational experiments, (2) biomedical and operational experiments that are more demanding of astronaut activity and a modest set of astronomical observations; and (3) experiments for the collection of significant scientific data by such instruments as solar and stellar ATM telescopes together with experiments concerned with earth resources, advanced technology, physics, and bioscience.

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(73) On the Question of Artificial Gravity, Memorandum for File, A. N. Kontaratos, August 23, 1968.

(74) Guidelines for Intermediate Space Station Payloads, Memorandum for File, F. G. Allen, July 3, 1968.

A study was carried out to estimate the allowable radiation limits for spacecraft carrying x-ray astronomy experiments. (75) Values of x-ray fluxes observed or anticipated in solar and steller astronomy experiments were given. These values provide design limits for local x-ray flux from sources on the spacecraft which may be difficult to meet for onboard radiation sources such as isotope power systems.

Planetary

A detailed method for calculating the equilibrium distribution of asteroids and their debris was developed. (76) Assuming a randomly-distributed population of objects in the asteroidal belt, it was shown that frequent collisions are inevitable and fragmentation will result. The steady state distribution of such a population was calculated and found to agree with observations. Asteroidal lifetimes were also estimated.

A paper describing a general method for calculating the mass distribution function of interplanetary objects undergoing statistically frequent collisions and fragmentation was published in NASA SP-150 ("The Zodiacal Light and the Interplanetary Medium") which was released during the quarter. (77) Theoretical conclusions and observational results are in satisfactory agreement.

A report was prepared documenting the first phase of work on the development of a haze model for the Mars atmosphere. (78) The basis for this empirical model was the Mariner IV television data. Work is continuing on the mathematical refinement of the model and plans are being formulated to further test the model using Mariner '69 television data.

One of the problems associated with the Mariner IV television data stems from the uncertainty in the photometric accuracy of this data. Onboard calibration during the photography mission would alleviate this problem. To this end the conceptual design of a test pattern projector for the wide angle Mariner '71 television camera has been described. (79) This device enables the

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(75) Spacecraft Radiation Limits Imposed by X-Ray Astronomy Experiments, Memorandum for File, F. F. Tomblin, August 29, 1968.

(76) Collisional Model of Asteroids And Their Debris, TR-68-710-4, J. S. Dohnanyi, July 22, 1968.

(77) Collisional Model of Meteroids, J. S. Dohnanyi, published in NASA SP-150, ("The Zodiacal Light and Interplanetary Medium").

(78) Haze in the Mars Atmosphere As Revealed by the Mariner IV Television Data, TR-68-710-6, P. L. Chandeysson, E. N. Shipley, W. B. Thompson, August 20, 1968.

(79) Test Pattern Projector for the '71 Mars Orbiter Television Camera, Memorandum for File, P. L. Chandeysson, September 9, 1968.

performance of the camera to be monitored throughout the mission by projecting a test pattern through the camera lens onto the vidicon.

In planning the photographic mission for the 1971 Mariner Mars orbiters, a reasonable prediction of the satellite orbit throughout the nominal 90 day mission is desirable. The orbit of such a satellite is subject to perturbations due to the oblateness of Mars. Calculations indicate approximately a $15^{o}$ change in the longitude of the ascending node and a $4^{o}$ change in the argument (angular position) of periapsis during the 90 day mission assuming an orbit inclination of $60^{o}$, a 12 hour period, and a 2000 km periapsis altitude. (80)

System requirements for a topside sounder experiment to explore the ionospheres of Mars and Venus from an orbiting spacecraft have been analyzed. (81) Comparing these requirements with those of a comparable experiment which has been carried out in earth orbit reveals that the planetary experiment would require lower operating frequencies (hence longer antennas), more transmitted power (because of greater collisional absorption), and better time resolution. Comparisons are made between the planetary topside sounder and occultation experiments in terms of requirements and expected data return. The occultation technique is suggested as the better approach for early orbital investigations of the ionospheres of Mars and Venus.

Several reports in support of the manned Mars and Venus encounter mission study effort were completed. One examined the feasibility of using a 40" telescope on the manned spacecraft to observe a flashing beacon on a probe either approaching Mars or landed on the Mars surface. (82) It was shown that the landed probe could be observed on a fully illuminated planet one hour before manned spacecraft encounter using a strobe light requiring an input of approximately 34 joules per flash.

Two reports identifying the system requirements for a multiple balloon probe and tracking system for investigating meteorological phenomena at Venus were prepared. A conceptual design of a probe capable of delivering superpressure balloons to several different altitudes in the Venusian atmosphere was

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(80) Secular Perturbations of a Near Mars Satellite, Memorandum for File, S. Bayliss, July 19, 1968.

(81) Design Parameters for an Orbiting Topside Sounder for Mars and Venus and Some Comparisons with the Orbiting Occultation Experiment, TR-68-710-5, W. R. Sill, July 30, 1968.

(82) Visual Observation of Planetary Probes on Manned Encounter Missions to Mars, Memorandum for File, C. L. Greer, September 19, 1968.

carried out.(83) This probe (or probes), together with a companion orbiter, would be delivered from a manned spacecraft. A technique was described for tracking the balloons floating in the atmosphere from the orbiter.(84) Assuming availability of both range and range rate data, expected balloon location accuracy was calculated and found to be strongly dependent on the distance of the balloon from the orbital plane.

As a continuation of previous work on planetary orbit determination problems, a numerical technique was devised for the approximate solution of a set of non-linear equations.(85) Simulations of the orbit determination problem have indicated that this approach, when compared with classical techniques, guarantees convergence for larger errors in the initial state vector estimate.

A possible method of meeting the tracking accuracy requirements of targeting various planetary probes with an earth-based multiple-link Doppler tracking system was studied.(86) The use of a planetary satellite as a navigational reference could in concept significantly reduce the uncertainties in planetary ephemerides which is the major source of interplanetary navigation errors.

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(83) Manned Venus Flyby Meteorological Balloon System, TM-68-1014-3, G. A. Briggs, E. M. Grenning, July 29, 1968.

(84) The Location by Satellite of Meteorological Balloons in the Atmosphere of Venus, Memorandum for File, G. A. Briggs, September 19, 1968.

(85) Approximate Solutions of M Nonlinear Equations in N Unknowns for $M \geq N$, TM-68-1014-5, C. L. Greer, August 6, 1968. Also presented orally at the 1968 National SIAM Meeting in Toronto, June 11-14. Submitted for publication in the "SIAM Journal on Numerical Analysis".

(86) Interplanetary Navigation - An Earth-Based Multiple-Link Doppler Tracking System, Memorandum for File, C. C. H. Tang, July 25, 1968.

## ADVANCED MANNED MISSIONS SYSTEMS ENGINEERING
## MISSION ANALYSIS

### Earth Orbital

Engine burn times and velocity losses due to gravity were computed as a function of the ratio of engine thrust to vehicle weight for two missions [87]:

1. Injection onto a translunar trajectory
2. Transfer from a 100 nm circular orbit to synchronous orbit altitude.

Data were obtained for two values of specific impulse representative of nuclear rockets and advanced cryogenic chemical rockets. A comparison was made of payload vs $\Delta V$ curves calculated for nuclear stages and for advanced hydrogen-oxygen stages. [88] The Nerva I size nuclear engine (75,000 lbs thrust) showed performance advantages for high $\Delta V$ missions in earth orbital maneuvering and translunar injection if the payload were large enough to require a Saturn V launch vehicle. These advantages were shown to be small unless the required $\Delta V$ was considerably larger than that required for a synchronous equatorial mission or unless nuclear systems can be designed with inert weights lower than currently estimated.

### Planetary

Probe deployment from elliptical parking orbits around Mars was studied. It was found that injection from a 24 hour orbit with a 100 nm periapsis can be performed for less than 100 fps but the range of entry anomalies is limited to 4 . [89] A $\Delta V$ of 1,000 fps would allow a 60° range in entry anomaly.

A paper was presented which reviewed previously reported work on three distinct classes of triple-planet (Earth-Venus-Mars-Venus-Earth) ballistic flybys, and the characteristics related to specific sequences of planetary geometries. [90]

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(87) Finite-Thrust Transfers to Synchronous Orbit and Translunar Injection, Memorandum for File, A. L. Schreiber, September 4, 1968.

(88) Comparison of Chemical and Nuclear Propulsion for Earth Orbital Maneuvering and Translunar Injection Stages, Memorandum for File, H. S. London, September 5, 1968.

(89) Probe Deployment to the Planet Mars from an Elliptical Parking Orbit, Memorandum for File, J. J. Schoch, July 19, 1968.

(90) Triple-Planet Ballistic Flybys of Mars and Venus, Paper No. 68-114, presented at the AAS/AIAA Astrodynamics Specialist Conference, Jackson, Wyoming, September 3-5, 1968, A.A. VanderVeen.

## ADVANCED MANNED MISSIONS SYSTEMS ENGINEERING CONFIGURATION STUDIES

The conceptual design of a Mars Excursion Module ascent propulsion vehicle to deliver a specific payload from the Martian surface to Mars orbit was completed. (91) The study identifies technological problems associated with such a design. The major emphasis focused on the handling problems of advanced space storable propulsion systems. Space storable propellants were found to be practical and to offer the advantages of lower vehicle weight and fewer stages relative to earth storables.

A preliminary parametric study evaluated the capability of common mission module configurations to support crew sizes of two or more men for two-year missions. (92) A number of possible internal configurations for crew quarters, control consoles, and other spacecraft subsystems were developed. The significant point illustrated by this study is that the module volume can have multiple uses.

Spacecraft thermal control was examined for the spectrum of missions beyond 0.25 AU from the sun. (93) Except for some lunar missions it was found that a single spacecraft thermal control system design for all such missions is feasible.

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(91) Mars Excursion Module Ascent Propulsion Stage Design, TM-68-1013-3, M. H. Skeer, July 8, 1968.

(92) Common Mission Module - Parametric Sizing Study, Memorandum for File, A. S. Kiersarsky, July 12, 1968.

(93) The Spacecraft Thermal Environment and Its Implications to CMM Design, Memorandum for File, R. Gorman, June 13, 1968.

## MISSION OPERATIONS STUDIES

The performance of the KSC Operational Intercommunication System-Audio (OIS-A), which was changed to a 4-wire configuration during the past year, was monitored during the Apollo 7 prelaunch tests (Plugs-In, Plugs-Out, Countdown Demonstration Test and Flight Readiness Test) at KSC and at MSC. The results of this monitoring were given to KSC for use in their overall system evaluation. The quality of the voice circuits was good and the occasional low level crosstalk was not judged objectionable. (94)

A study was made of voice and data relay from a space vehicle orbiting the earth over several types of Intelsat communication satellites. The study indicated the feasibility of such a relay for Intelsat III and Intelsat IV. For example, a digital voice channel to earth could be provided via an Intelsat III from a spacecraft with a 10 watt transmitter and a 5.5 ft diameter antenna. (95)

An analysis was made of efficient decision criteria for a pulse position modulation receiving system typical of those used in optical communication systems. (96)

A study was made of the possible reduction in the number of MSFN land station and ships, Apollo/Range Instrumentation Aircraft (A/RIA), and recovery ships and aircraft if the launch window for Apollo-type lunar missions were shortened. It was shown that in such a case significant reductions could be made in support facilities. (97)

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(94) Operational Intercommunication System Monitoring at KSC During Apollo 7 CDDT, Memorandum for File, B. F. O'Brien, September 25, 1968.

(95) The Use of Intelsat Satellites for Direct Voice Communications with Manned Space Vehicles, TM 68-2034-15, R. K. Chen, September 30, 1968.

(96) A Simple and Efficient Decision Criterion for Operation in a Pulse Position Modulation System When Both Signal and Noise are Poisson Distributed, TM-68-2034-12, L. Schuchman, July 10, 1968.

(97) Reduced Support Needed for Lunar Mission with Shortened Launch Windows, TM-68-2013-4, P. A. Cavedo, T. B. Hoekstra, September 23, 1968.

Real-time support requirements for ALSEP were analyzed. (98) An evaluation of several proposals for creating a real-time support facility was made at the request of the Mission Operations Director. It was concluded that MSC, by virtue of existing computers and mission control expertise, was best qualified to perform the job in the required time frame. Several recommendations for reducing costs at MSC were made. (99)

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(98) Apollo Lunar Surface Experiments Package Support System Sizing Estimates, Memorandum for File, R. J. Pauly, August 19, 1968.

(99) ALSEP Flight Support Systems Evaluation, Memorandum for File, B. H. Liebowitz, R. J. Pauly, September 6, 1968.

## SPECIAL TASK ENGINEERING STUDIES ASSISTANCE IN CERTAIN COMPUTER OPERATIONS AND RELATED ACTIVITIES

### TASK ORDER NO. 12

During the period from July 1, through September 30, NASA usage of the UNIVAC 1108 computer was 34.028 hours. There was no independent usage (non-NASA) of the 1108 computer during this time.

## GENERAL MISSION ENGINEERING STUDIES

### Long Range Planning

Support of NASA Planning System activities to develop the Agency's FY70 and longer term plans was continued. Draft chapters of the forthcoming Bellcomm report on this subject were transmitted to the Chairman of the Planning Steering Group along with observations on the planning process. The drafts included:

- Chapter 2 - "Program Rationale and Approach"

Outlines the current rationale and approach determined by the Planning Steering Group for each of the following Program Categories selected for the FY70 Program and comments on the omissions, inconsistencies, and errors in the statements of rationale and approach.

1. Extension of Manned Space Flight Capability Program
2. Lunar Exploration Program
3. Planetary Exploration Program
4. Astronomy Program
5. Space Physics Program
6. Space Biology Program
7. Aircraft Technology Program
8. Advanced Space Technology Program
9. Space Applications Program
10. Supporting Activities Program.

- Chapter 3 - "Program Category Interfaces"

Identifies the overlaps, interfaces, and common elements between and among the various Program Categories.

- Chapter 4 - "NASA Program Strategies"

Examines and elaborates upon the Agency program strategies identified by the Planning Steering Group for meeting the Agency goals and objectives.

- Chapter 5 - "NASA Program Alternatives"

Summarizes the results of synthesis of NASA program alternatives that implement the program strategies defined in Chapter 4.

- Chapter 6 - "Program Characterization"

Characterizes the Agency program alternatives synthesized in Chapter 5 in order to provide a basis for their evaluation.

Presentations were made to the Planning Steering Group and the Management Council covering the work and observations on the critical issues in the planning activity.

Inertial Navigation Error Estimation

A method for approximating the state vector error due to inertial space navigation equipment errors was developed and compared successfully with results from more elaborate methods.(100)

Surface Temperature of Venus

It has been shown that the microwave interferometer now operating at Greenbank, West Virginia, can be configured to yield significant information on the properties of the Venusian surface and atmosphere during the inferior conjunction in May 1969. Such information would be valuable for the planning and design of future missions. Discussions have been held with personnel at the National Radio Astronomy Observatory who have agreed to carry out measurements. Effective use of the facilities for procuring mission oriented data requires, among other preparatory steps, the calculation of the so-called visibility functions which describe the emission from planetary radio sources. A perturbation scheme which provides an order of magnitude estimate for the several effects determining the visibility function has been completed and shows that variation of temperature has the largest effect on the visibility function.(101)

Electromechanical Component Replacement

A brief study was completed regarding the state of the art of replacing small electromechanical components by solid-state devices.(102) It was found that, in general, replacement would not be made on a one-for-one basis. Relays and circuit breakers are relatively easy to replace with solid-state devices

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(100) Inertial Navigation Error Estimation for Space Missions, TM-68-2014-5, W. B. Gevarter, September 25, 1968.

(101) An Investigation of the Factors Affecting Planetary Radio Visibility Functions, TM-68-1014-6, I. O. Bohachevsky, September 20, 1968.

(102) Replacement of Electromechanical Components by Solid State Components, Memorandum for File, D. O. Baechler, P. S. Schaenman, July 23, 1968.

in new or redesigned systems. Hand-operated switches pose a greater problem, but several promising technologies are under development.

Spaceborne Computer Digital Storage

Estimates were made of the state-of-the-art of aerospace digital storage devices expected in the early 1970's.(103) Many technologies, such as Metal Oxide Semiconductor (MOS), thin film, plated wire, and laminated ferrites appear promising. Memories with less weight and lower power consumption than core memories are to be expected.

Inflight Skill Retention

The need for maintaining crew skills on long duration manned missions was studied. (104) It was concluded that the ability of the crew to perform certain tasks might degrade significantly in the course of the mission. If this skill degradation is significant, inflight training requirements could have major effects on the design of spacecraft subsystems. Various experiments were therefore proposed to determine what degree of skill degradation should be expected and what provisions will be necessary to prevent it.

Slidell Computer Operations Study

Responding to an OMSF request, Bellcomm joined with a Headquarters and MSFC team in initiating a study of the NASA computing complex at Slidell, Louisiana. The purpose of the study is to determine the most effective method of continuing computer support, commensurate with approved programs and options.

ADP Management

A study was begun to determine key factors to be considered in an evaluation of computer installations. A presentation describing the purpose and output of the task was given to the MSF Resources Sharing Panel. In conjunction with this task, Bellcomm has become a member of the USA Standards Institute Subcommittee X3.6.2 for Computer Performance Evaluation.

Computer Reliability

The impact of failure and repair rates upon computer availability was examined. (105) A nonstationary stochastic model which is useful in analyzing

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(103) Future Spaceborne Memories with $10^3$-$10^7$ Bit Capacities, TM-68-1031-4, B. W. Kim, July 26, 1968.

(104) Inflight Maintenance of Crew Skills on Long-Duration Manned Missions, TM-68-1031-2, J. R. Birkemeier, July 30, 1968.

(105) On the Reliability of Computer Operations, TM-68-1033-5, G. L. Yang, September 13, 1968.

the reliability of computer operations was developed. Study of Bellcomm's UNIVAC 1108 system failure data indicates that (1) computer hardware failures are time dependent in occurrence, (2) the usual assumption of a constant failure rate may not be applicable in setting up a reliability model, and (3) computer failure rates probably vary with usage patterns. This study is being extended to include analysis of MSC computer system data.

Angular Momentum Transfer: Solar Chromosphere

A presentation was made to the American Astronomical Society describing calculations to determine the angular momentum transfer rate through the solar chromosphere based on the height dependence of solar rotation rate.(106) It was concluded that the momentum exchange through the chromosphere may be sufficient to drive the solar differential rotation.

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(106) Angular Momentum Transfer Through the Solar Chromosphere, Paper presented at the American Astronomical Society Meeting, University of Victoria, British Columbia, Canada, August 20-23, 1968, R. M. Ashby (North American Rockwell Corp., Autonetics Division), A. N. de Gaston (Bellcomm).

## ENGINEERING SUPPORT

### Computing Facility

Bellcomm's UNIVAC 1108 Computer System was shut down from August 29 to September 20 incident to the company's move to L'Enfant Plaza. During that period the 1108 Computer at the University of Maryland was used to provide necessary computations.

The UNIVAC 1108 computer operations were continued under the EXEC II batch processing system. Extensive testing and evaluation of the multiprogramming EXEC 8 system is being performed by Bellcomm and UNIVAC personnel. Most of the programs that are part of the contractual testing of the EXEC 8 system have been made to run with EXEC 8, and an evaluation of EXEC 8 throughput is in progress. The system does not yet meet contractual requirements.

Programming support for the various Bellcomm engineering and scientific studies was continued during the report period.

## ADMINISTRATIVE

### Relocation to L'Enfant Plaza

Bellcomm's move to 955 L'Enfant Plaza North, Southwest, Washington, D. C., was completed on September 1, 1968. A TOP SECRET facility clearance for this location was granted on September 16, 1968 by the Defense Contract Administrative Service Region, Philadelphia.

### Cost Reduction Program

Bellcomm reported a savings of $15,500 for the six month period ending June 30, 1968 as a result of its cost reduction efforts.

## LIST OF REPORTS AND MEMORANDA

(Listed in Order of Report Date)

This index includes technical reports and memoranda reported during this period covering particular technical studies.

The memoranda were intended for internal use. Thus, they do not necessarily represent the considered judgment of Bellcomm which is reflected in the published Bellcomm Technical Reports.

| TITLE | DATE |
|---|---|
| The Spacecraft Thermal Environment and Its Implications to CMM Design, Memorandum for File, R. Gorman | June 13, 1968 |
| Minutes of the (GLEP) Site Selection Subgroup Meeting of June 19, 1968, Memorandum for File, F. El-Baz | July 3, 1968 |
| Guidelines for Intermediate Space Station Payloads, Memorandum for File, F. G. Allen | July 3, 1968 |
| Spacecraft Shadowing and Thermal Flux Computer Programs with Sample Problems, Memorandum for File, J. W. Powers | July 8, 1968 |
| Mars Excursion Module Ascent Propulsion Stage Design, TM-68-1013-3, M. H. Skeer | July 8, 1968 |
| LM Launch Atmosphere Alternatives, Memorandum for File, R. D. Raymond | July 10, 1968 |
| A Simple and Efficient Decision Criterion for Operating in a Pulse Position Modulation System when both Signal and Noise are Poisson Distributed, TM-68-2034-12, L. Schuchman | July 10, 1968 |
| Common Mission Module - Parametric Sizing Study, Memorandum for File, A. S. Kiersarsky | July 12, 1968 |
| Critical Design Review of ATM Experiment S-054, X-Ray Spectrographic Telescope, Memorandum for File, S. H. Levine, T. C. Tweedie, Jr. | July 15, 1968 |

| TITLE | DATE |
|---|---|
| AAP-1A - A Baseline Instrument Package for Earth Sensing, Memorandum for File, W. W. Elam | July 15, 1968 |
| Safety-Rescue Escape APO Briefing, Memorandum for File, G. B. Troussoff | July 18, 1968 |
| Distribution of Elevations on a Cratered Planetary Surface, TR-68-340-4, A. H. Marcus | July 18, 1968 |
| Electrical Power Requirements for AAP-3A, Memorandum for File, B. W. Moss | July 19, 1968 |
| Review of AAP I/C Panel Instrumentation and Communications Interface Control Documents, Memorandum for File, A. G. Weygand | July 19, 1968 |
| Preliminary Evaluation of AS-502 Color Photography of Earth Resources, Memorandum for File, B. E. Sabels | July 19, 1968 |
| Secular Perturbations of a Near Mars Satellite, Memorandum for File, S. Bayliss | July 19, 1968 |
| Probe Deployment to the Planet Mars from an Elliptical Parking Orbit, Memorandum for File, J. J. Schoch | July 19, 1968 |
| Collisional Model of Asteriods And Their Debris, TR-68-710-4, J. S. Dohnanyi | July 22, 1968 |
| Preliminary Findings--Flame Propagation Dependence on Atmospheric Oxygen, Memorandum for File, S. S. Fineblum | July 23, 1968 |
| A Titan-IIIM Launched Space Station Program, Memorandum for File, E. D. Marion, J. A. Schelke | July 23, 1968 |
| Replacement of Electromechanical Components by Solid State Components, Memorandum for File, D. O. Baechler, P. S. Schaenman | July 23, 1968 |
| Workshop Cost Estimates Based on EOSS, MORL, and BSM Costs, Memorandum for File, A. E. Marks | July 25, 1968 |

| TITLE | DATE |
|---|---|
| Interplanetary Navigation - An Earth-based Multiple-Link Doppler Tracking System, Memorandum for File, C. C. H. Tang | July 25, 1968 |
| Determination of SM RCS Propellant Requirements for AAP and Apollo Rendezvous, Memorandum for File, K. E. Martersteck | July 26, 1968 |
| Future Spaceborne Memories with $10^3$-$10^7$ Bit Capacities, TM-68-1031-4, B. W. Kim | July 26, 1968 |
| Manned Venus Flyby Meteorological Balloon System, TM-68-1014-3, G. A. Briggs, E. M. Grenning | July 29, 1968 |
| Design Parameters for an Orbiting Topside Sounder for Mars and Venus and Some Comparisons with the Orbiting Occultation Experiment, TR-68-710-5, W. R. Sill | July 30, 1968 |
| Inflight Maintenance of Crew Skills on Long-Duration Manned Missions, TM-68-1031-2, J. R. Birkemeier | July 30, 1968 |
| ATM Experiments - Time Requirements, Memorandum for File, A. N. de Gaston | August 1, 1968 |
| A Discussion of the Proposed Two Burn Lunar Orbit Insertion Maneuver, Memorandum for File, D. A. Corey | August 5, 1968 |
| Lightweight (Roll-up) Solar Array Development, Memorandum for File, J. J. Sakolosky | August 5, 1968 |
| Performance Improvement for AAP-2, Memorandum for File, B. W. Moss | August 5, 1968 |
| An Analysis of Orbital Resonance for the Determination of Lunar Gravitational Harmonic Coefficients, Memorandum for File, A. J. Ferrari | August 6, 1968 |
| Covariance Function of Elevations on a Cratered Planetary Surface, Part II: Crater Rim and Ejecta Blanket Contribution, TR-68-340-5, A. H. Marcus | August 6, 1968 |

| TITLE | DATE |
|---|---|
| Scientific Evaluation of Alternative ATM Missions at High Inclination, Memorandum for File, D. B. Wood | August 6, 1968 |
| Approximate Solutions of M Nonlinear Equations in N Unknowns for $M \geq N$, TM-68-1014-5, C. L. Greer | August 6, 1968 |
| A Simple Method for Approximating Quantiles of Random Variable $X_1^2 + X_2^2 + X_3^2$, Memorandum for File, H. J. Bixhorn, B. G. Niedfeldt | August 9, 1968 |
| A Statistical Analysis of a Bandpass Nonlinearity - Phase Detector Cascade, TM-68-2034-14, W. D. Wynn | August 9, 1968 |
| ATM Alternative Mission Study: Impact of Computer Systems, Memorandum for File, R. T. Kleiner, B. H. Liebowitz, P. S. Schaenman | August 9, 1968 |
| Propagation Characteristics of the Apollo Dual-EVA Communication Links, TM-68-2034-13, K. H. Schmid | August 12, 1968 |
| LPM Landing and 14 Day CSM Orbital Missions, Memorandum for File, I. Silberstein | August 12, 1968 |
| ATM Alternative Mission Study - Communications Coverage, Memorandum for File, J. P. Maloy | August 12, 1968 |
| Nickel-Cadmium Secondary Batteries, Memorandum for File, B. W. Moss | August 12, 1968 |
| Spacecraft Weight Summary for CM-SM/LM-ATM Backup Missions, Memorandum for File, W. W. Hough | August 13, 1968 |
| Structural Considerations in CM-SM/LM-ATM Backup Mission, Memorandum for File, W. W. Hough | August 13, 1968 |
| Range Safety System Operations During Saturn V Launch Countdowns, Memorandum for File, G. J. McPherson, Jr. | August 14, 1968 |

| TITLE | DATE |
|---|---|
| Pointing Stability of a CM-SM/LM-ATM, Memorandum for File, J. Kranton | August 14, 1968 |
| Radiation Doses for the CM-SM/LM-ATM Alternate Mission Study, Memorandum for File R. H. Hilberg, J. S. Ingley | August 14, 1968 |
| Apollo Lunar Surface Experiments, Package Flight Support System Sizing Estimates, Memorandum for File, R. J. Pauly | August 19, 1968 |
| Haze in the Mars Atmosphere As Revealed by the Mariner IV Television Data, TR-68-710-6, P. L. Chandeysson, E. N. Shipley, W. B. Thompson | August 20, 1968 |
| Angular Momentum Transfer Through the Solar Chromosphere, Paper presented at the American Astronomical Society Meeting, University of Victoria, British Columbia, Canada, R. M. Ashby (North American Rockwell Corp.), A. N. de Gaston (Bellcomm) | August 20-23, 1968 |
| Safe Distance for the ALSEP Emplacement, Memorandum for File, G. K. Chang | August 22, 1968 |
| Initial Thrust Mistrim and c.g. Motion Effects on Translunar and Transearth Midcourse Correction Maneuvers, Memorandum for File, F. La Piana | August 22, 1968 |
| Problems in Radiation Dose Calculations in Spacecraft, I: Electrons, TM-68-1011-3, J. S. Ingley | August 23, 1968 |
| ALSEP Derived Contingency Science, Memorandum for File, M. T. Yates | August 23, 1968 |
| On the Question of Artificial Gravity, Memorandum for File, A. N. Kontaratos | August 23, 1968 |
| LM Supercritical Helium (SHe), System - Status of Lunar Mission Requirements/Capabilities and Proposed Uprating, Memorandum for File, D. M. Duty | August 28, 1968 |
| Critical Design Review of the ATM S082A XUV Coronal Spectroheliograph and the S082B XUV Spectrograph Experiments, Memorandum for File, S. H. Levine, T. C. Tweedie, Jr | August 28, 1968 |

| TITLE | DATE |
|---|---|
| Spacecraft Radiation Limits Imposed by X-Ray Astronomy Experiments, Memorandum for File, F. F. Tomblin | August 29, 1968 |
| ATM Alternate Mission Study-Performance Analysis, Memorandum for File, I. Hirsch, K. E. Martersteck | September 3, 1968 |
| Triple-Planet Ballistic Flybys of Mars and Venus, Paper No. 68-114 presented at the AAS/AIAA Astrodynamics Specialist Conference, Jackson, Wyoming, A. A. VanderVeen | September 3-5, 1968 |
| Selection of a Digital Computer to Support ATM Functions, Memorandum for File, P. S. Schaenman | September 4, 1968 |
| Finite-Thrust Transfers to Synchronous Orbit and Translunar Injection, Memorandum for File, A. L. Schreiber | September 4, 1968 |
| Solar Viewing Capability in High Inclination Circular and Elliptical Earth Orbits, TM-68-1022-5, B. D. Elrod | September 5, 1968 |
| Correlation of Predicted, Ground Test, and Flight Thermal Behavior in Apollo, Memorandum for File, D. P. Woodard | September 5, 1968 |
| Status of Electromagnetic Interference Control in the Apollo Applications Program, Memorandum for File, A. G. Weygand | September 5, 1968 |
| Comparison of Chemical and Nuclear Propulsion for Earth Orbital Maneuvering and Translunar Injection Stages, Memorandum for File, H. S. London | September 5, 1968 |
| Gravity-Gradient Momentum Dumping for a CM-SM/LM-ATM Mission, Memorandum for File, W. Levidow | September 6, 1968 |
| ATM Alternate Mission Study Summary, Memorandum for File, G. M. Anderson | September 6, 1968 |
| ALSEP Flight Support Systems Evaluation, Memorandum for File, B. H. Liebowitz, R. J. Pauly | September 6, 1968 |
| Selection of CM Cameras for Apollo Lunar Photography, Memorandum for File, D. D. Lloyd | September 9, 1968 |

| TITLE | DATE |
|---|---|
| CM-SM/LM-ATM Alternate Mission Study - Electrical Power Requirements, Memorandum for File, B. W. Moss | September 9, 1968 |
| Test Pattern Projector for the '71 Mars Orbiter Television Camera, Memorandum for File, P. L. Chandeysson | September 9, 1968 |
| Unmanned Lunar Logistic Systems, Memorandum for File, R. Sehgal | September 9, 1968 |
| Influence of Weight Changes on AS-503 Structural Longitudinal Mode Shapes and Frequencies, Memorandum for File, H. E. Stephens | September 10, 1968 |
| Apollo Circuit Breakers as Ignition Sources, Memorandum for File, W. H. Hodge | September 11, 1968 |
| On The Reliability Of Computer Operations, TM-68-1033-5, G. L. Yang | September 13, 1968 |
| Pinpoint Landing for a Lunar Payload Module, TM-68-2015-4, H. W. Radin | September 16, 1968 |
| Visual Observation of Planetary Probes on Manned Encounter Missions to Mars, Memorandum for File, C. L. Greer | September 19, 1968 |
| The Location by Satellite of Meteorological Balloons in the Atmosphere of Venus, Memorandum for File, G. A. Briggs | September 19, 1968 |
| Electron Delocalization and Aromaticity: Their Effect on the Thermal Stability of Polymeric Materials, Memorandum for File, M. V. Drickman | September 20, 1968 |
| A Proposed 2 Color Photographic CSM Experiment, Memorandum for File, A. F. H. Goetz | September 20, 1968 |
| A Single Axis, Two Maneuver Gravity-Gradient Dump Procedure for AAP-ATM Missions, TM-68-1022-4, W. Levidow | September 20, 1968 |
| An Investigation of the Factors Affecting Planetary Radio Visibility Functions, TM-68-1014-6, I. O. Bohachevsky | September 20, 1968 |

| TITLE | DATE |
|---|---|
| Final Report - Apollo Guidance Software Task Force, W. G. Heffron (Secretary, Apollo Guidance Software Task Force) | September 23, 1968 |
| MSFN Navigation Support in Earth Parking Orbit, Memorandum for File, R. M. Scott | September 23, 1968 |
| Power Margins for the LM-MSFN (85') Communications Link at Lunar Range, Memorandum for File, N. W. Schroeder | September 23, 1968 |
| Application of a Dynamic Density Model to the Simulation of Earth Orbit Trajectories, TM-68-1025-2, A. B. Baker | September 23, 1968 |
| Reduced Support Needed for Lunar Missions with Shortened Launch Windows, TM-68-2013-4, P. A. Cavedo, T. B. Hoekstra | September 23, 1968 |
| Lunar CSM Photography Working Group Meeting on Lunar Photography for the C' and F Missions, Memorandum for File, D. D. Lloyd | September 24, 1968 |
| To "G" or not to "G", Memorandum for File, E. D. Marion | September 24, 1968 |
| Operational Intercommunication System Monitoring at KSC During Apollo 7 CDDT, Memorandum for File, B. F. O'Brien | September 25, 1968 |
| Inertial Navigation Error Estimation for Space Missions, TM-68-2014-5, W. B. Gevarter | September 25, 1968 |
| The Influence of CSM-103 Hypergol Subsystem Lifetimes on C Prime Mission Launch Opportunities, Memorandum for File, C. H. Eley III | September 26, 1968 |
| LM-A Thermal Control System, Memorandum for File, D. P. Woodard | September 27, 1968 |
| Summary of a Detailed Study of the Apollo Up-Data System, TM-68-2034-16, R. L. Selden | September 29, 1968 |
| Reduction in Lunar Surface Visibility Due to Glare During a Landing into the Sun, TM-68-2013-5, R. Troester | September 30, 1968 |

| TITLE | DATE |
|---|---|
| Star Sighting Problems Due to Light Scatter from RCS Plume Residue on Apollo Spacecraft Optics, Memorandum for File, R. Troester | September 30, 1968 |
| An Evaluation of the Concept of Crew Member Radiation Standards, Memorandum for File, R.H. Hilberg, R.K. White | September 30, 1968 |
| Jettisonable Enclosure for Unmanned AAP Payloads, Memorandum for File, W.W. Hough | September 30, 1968 |
| Multiple Docking Adapter Thermal Control System, Memorandum for File, J.W. Powers | September 30, 1968 |
| Stability of Attitude Motion of an Orbiting Vehicle Containing a Gyrostat, TM-68-1022-8, E.Y. Yu | September 30, 1968 |
| The Use of Intelsat Satellites for Direct Voice Communications with Manned Space Vehicles, TM-68-2034-15, R.K. Chen | September 30, 1968 |
| Requirement for an Oxygen Accumulator on AAP-2, Memorandum for File, W.W. Hough | October 1, 1968 |
| A Look at Utilization of Off-Peak Electrical Power for Water Electrolysis, Memorandum for File, J.J. Sakolosky | October 8, 1968 |
| Response of the Moon to the Time-Varying Interplanetary Magnetic Field, Paper submitted for publication to the "Journal of Geophysical Research", J.L. Blank, W.R. Sill | To be published |
| Collisional Model of Meteroroids, Paper published in NASA SP-150, The Zodiacal Light and Interplanetary Medium, J.S. Dohnanyi | |

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